SUBSTITUTE SPECIFICATION

Docket No: 542-023.002
Serial No. 10/527,483
September 1, 2006

METHOD AND ARRANGEMENT FOR MEASURING CONDUCTIVE COMPONENT CONTENT OF A MULIPHASE FLUID FLOW AND USES THEROF.

CROSS REFERENCE TO RELATED APPLICATION

This application is the U.S. National Stage of International Application PCT/NO2003/000313 filed 10 September 2003 and published in English on March 25, 2004 under International Publication No. WO 2004/025288 claiming priority from Norwegian Patent Application No. 20024332 filed 10 September 2002.

BACKGROUND OF THE INVENTION

1. Technical Field

The present invention relates to a method and arrangement for measuring conductive component content of a muliphase fluid flow. Applications of the method and arrangemet are also disclosed.

2. Discussion of Related Art

In particular the method and arrangement are well suitable for determining a water content in flows, in particular in mixtures of oil, HC-gases and water, in a fluid transporting body.

The water fraction meters used in the oil process industry today will all be influenced by the gas content in the oil/water/gas-mixture and different kinds of iterative algorithms are used to compensate for this error. Microwave meters are dependent on the salinity of the water component in both oil and water continuous phases and capacitance meters must be equipped with a conductivity meter to cover the whole range of water fraction from 0 to 100%.

DISCLOSURE OF INVENTION

The object of the present invention is to provide for a method and arrangement to be able to effect determining the content of a conductive fraction in a multiphase flow wherein the conductive phase exist in a range of being continuous or being included in the muliphase flow as droplets.

A multi phase flow of water/oil/gas may exhibit a water-continuous phase or an oil-continuous phase, for example.

In particular the purpose of the invention is to provide for a method and apparatus to determine the conductive water phase in said whole range of water-continuous and oil-continuous phases.

The method according to present invention is characterized by on line measuring the fraction of the conductive component in the multi phase flow by using a coil design optimized for non-conductive continuous mixtures, and a coil optimized for conductive continuous mixtures.

The preferred embodiments appear as described below in detail.

The arrangement according to present invention is for determining water content in multi phase flows in a fluid transporting body comprising a coil design optimized for non-conductive continuous mixtures, and a coil optimized for conductive continuous mixtures. Preferred embodiments of the arrangement appear in detail below.

According to the invention, the above-mentioned method and arrangement, are suitable for determining the water content of a multi phase flow of oil, hydrocarbon gases and water, in that water is the conductive component to be determined, and the oil and gas phases being the non-conductive phase.

According to a specific embodiment, the method is used for measuring the water content in oil/gas/water multiphase mixture flows wherein the different phases in the crude are separated, i. e. not homogeneously mixed.

In the following, the invention will be disclosed in relation to a multi phase mixture of water, oil and gas, while it should be evident that it may be applied to any multi phase mixture including one liquid conductive phase.

The water fraction meter described thus can detect the water fraction in three phase flows on line independent of the gas content in the mixture. Today the conductivity of the water component is determined off line by laboratory tests of processed water. The described instrument can monitor the water conductivity on line.

BRIEF DESCRIPTION OF THE INVENTION

The invention will be explained more in detail by referring to the enclosed drawing figures, in which:

Figure 1 shows a section of the arrangement/instrument (the meter spool principle) according to the invention.

Figure 2 shows a curve of the penetration depth as a function of the frquency of the coil, i. e. the skin depth in micrometers of the Cu lead (conductor) of the coil as a function of frequency (Mhz).

Figure 3 shows the result of an experiment measuring an oil/gas/water mixture phase with a particular coil design, with the impendance shown as a function of the water fraction in a multi phase flow to be determined. This coil design is sensitive for the water content in the mixture over the whole range, i. e. from the oil continuous phase to the water continuous phase. The steep area of the curve represents the transition area between the oil-continuous (left side of curve) and water-continuous phases (right side of curve).

Figure 4 shows the results of measurements effected with a coil which has increased sensitivity for oil/gas continuous mixtures (the left side of curve).

Figure 5 shows the measurement results of using a coil configuration of an increased sensitivity for water continuous mixtures (right hand side of curve).

Figure 6 shows an arrangement for utilizing this induction principle in a tomographic arrangement.

Figure 7 shows a a detail of a coil unit design which is connected to the pipe surface.

BEST MODE FOR CARRYING OUT THE INVENTION

MEASUREMENT PRINCIPLE

A sketch of the meter spool pipe principle is shown in the enclosed figure 1. There is shown an electrical insulated liner 10 (a coil pipe) around which excitation and detection coils 12,14 are arranged. The insulated liner may be a pipe prepared of a ceramic, plastic or a peek material and is, with all elements installed, arranged to be inserted in fluid flow conducting pipe. The coils 12,14 are protected by a screen (a steel material) 16 enclosing the central pipe section. The space between the screen and the pipe outer surface is filled with an inert material. The purpose of'the screen to make resistance to the fluid flow pressure inside the liner 10. Each coil having reference numbers 12 and 14 is used as an exitation coil and a detection coil. The coils are parts of an oscillator unit supplying alternating voltage to the coils. The oscillator frequency is dependent on the inductance and capacitance of each coil. Each coil 12 and 14 includes a different number of coil windings. The coil wires are preferably made of flat Cu-lices (copper), of a rectangular cross section, the thickness of which being up to 40 um in order to avoid any influence of changing resistance as the frequency is changing. This appears in figure 1. The direction of the multi phase flow through the pipe is shown by F.

Each coil (12 or 14 in figure 1) can be regarded as a parallel coupling between an inductance, a capacitance and a resistance. The capacitance consists of different spread capacitances between the coil windings and an equivalent parallel resistance made up by the resistance in the coil windings and the power loss in the volume of the mixture flowing through the coil. The first one is constant but the second one is dependent on the amount of water in the mixture. The coil is part of a feedback circuit which latches the excitation frequency to the coil's resonant frequency. The current in the feedback loop will then be dependent on the induced power loss in the mixture. The resonant frequency can be determined by the number of windings in the coil and the optimal frequency range will be dependent on the current penetration depth and the induced power loss in the multi phase flow mixture. The higher the frequency the higher is the loss and thus the higher is the sensitivity of the meter, but the frequency is limited by the current penetration depth of the induced current in both the mixture and the coil windings.

In oil/gas continuous mixtures the water consists as insulated droplets in the oil/gas. The induced loss in these distributed droplets is small compared to the loss in water continuous mixtures (this is the reason for making the power transformer cores of thin insulated steel plates). However, the penetration depth of the eddy currents is large so we can use a higher resonance frequency and thus increase the sensitivity.

Due to this fact two coils are used in the meter according to the invention, and they are simultaneously optimized for oil/gas continuous mixtures and water continuous mixtures respectively.

The induced loss will be dependent on the conductivity in the water component. By using two different coils with different resonance frequencies it is possible to compensate for variation in the conductivity and hence the conductivity of the water can be determined as well.

To keep the coil resistance constant it is important to avoid the frequency dependent resistance in the coil windings due to the electrical penetration depth. This can be avoided by winding the coil with a cable of separately insulated Cu-lices with a radius less than the electrical skin depth of Cu. In our experiment we have used flat Cucords at a thickness of 40 um.

THEORY

The eddy current loss in an infinitely large plate with thickness d (meter) and electrical conductivity σ ohm-meter)$^{-1}$, penetrated by a magnetic field B (Tesla) parallel the plate at a frequency w (radians/second), is:

(1)
$$P_0 = \frac{\sigma\omega^2 d^2 B^2}{12}$$

where B is the rms-value of the penetrating magnetic field, a the conductivity of the medium and. co the frequency of the magnetic field. The resonance frequency for the different coils lays in the region of 2 to 8 MHz and the electrical conductivity in processed water from the North Sea oil is 4-6 (ohm-meter)$^{-1}$.

The skin depth for the electrical current induced in a conducting medium is:

$$\delta = \sqrt{\frac{2}{\mu_o \mu_r \omega \sigma}}$$

(2)

where μ_o and μ_r are the magnetic permeability for the empty space and the relative permeability respectively.

At a frequency of 5.5 MHz which is used for the most sensitive coil for water continuous mixtures the penetration depth for the eddy currents will approximately be 10 cm. This is acceptable for production pipes up to a diameter of 20 cm (8"). The frequency may prefreably be in the range of 1-10 MHz, and most preferably in the range of 2 to 8 MHz.

The skin depth in micrometers of the Cu lead in the coil as a function of frequency (Mhz) is shown in the following Figure 2. The figure shows that the thickness of the Culead preferably is up to 40μm.

The coil design of the instruments used in the experiments are as follows:

Fig. 3. Nine layer 9 windings of flat Cu-cord (15 x 0.04 mm). f = 5.5 MHZ

Fig. 4. One layer, 15 windings of flat Cu-cord, f = 2 MHz

Fig. 5.4 layers, 4 winding coil of flat Cu-cord. f = 9 kHz.

EXPERIMENTAL RESULTS

Fig. 3. shows the meter result from a 9-turn coil which is sensitive for the water content in the mixture over the whole range. The impedance kΩ is shown as a function of the water fractionβ. The diagram shows that with this meter coil structure the whole range may be determined by the use of one coil only. A change in water content will effect a determinable (or visible) change in the impedance over the whole range.

Fig. 4. shows a coil which has an increased sensitivity for oil/gas continuous mixtures. Thus, in the oil/gas continous range, there is marked reduction in impedance as the water fraction increases and a change of water content in the fluid mixture is possible to measure in this range. But it is almost impossible to measure a change in water fraction exeeding about 0.275, as the impedance remains constant within said range.

Fig. 5. gives the result from the application of a coil configuration that has an increased sensitivity for water continuous mixtures. Thus, in the water continuous range, there is a marked reduction in impedance as the water fraction increases, and therefore a change of water content in the fluid mixture is possible to measure in this range. But it is almost impossible to measure a change in water fraction up to about 0.2 as the impedance does not change much within this range.

By combining those two last coils used in example 4 and 5, in a meter according to the invention, an increased sensitivity can be obtained both in water discontinuous mixtures and water continuous mixtures.

THE PRINCIPLE USED IN PROCESS TOMOGRAPHY

When the different phases in the crude are separated, i. e. not homogeneously mixed, the water content can not be measured with the same accuracy as for homogeneous mixtures if the principle explained above is used.

The arrangement for utilizing this induction principle in a tomographic arrangement is shown in Fig. 6.

Fig. 6. is a proposed coil arrangement which coils together form a meter for tomographic detection of multiphase flow. The figure shows a pipe section 20 of the same material as illustrated in figure 1. To the outside surface of the pipe 20, a number of 8 coil units 22 are mounted in close contact with the pipe surface 24. The three phases of gas 26, oil 28 and water 30 are shown inside the pipe section. The water amount may now be measured by means of the arrangement according to figure 6.

A more detailed drawing of one of the coils 22 is shown in figure 7.

Here we can determine the power loss generated in the alternating magnetic field from one coil at a time. Based on mathematical models of the magnetic field from the coils it is possible to work out a reconstruction algorithm for imaging the water distribution in the meter cross section. It may also be possible to excite one of the coils at a time and use all the other coils as pick up coils and detect the attenuation of the magnetic field from the transmitter to the receiver coils and thus

reconstruct a picture of the area of low field penetration which must be areas of water.

In the new solution, a different electronics is used. Here a resonance circuit is used wherein the resonance frequency changes as a function of changes in water content and salinity. Also the impedance at resonance changes due to these changes. By using a resonance circuit the frequency is always locked at the resonance frequency, wherein the sensitivity for changes is greatest. Thus one saves one coil so that the new solution is cheaper and simpler.

In an oil-water mixture the flow may be divided in oil-continous flows at low water fractions and water- continous flows at low oil fractions. As can be seen from the plot, where the impedance is plotted as a function of the water fraction, the curve exhibits a discontinuity. At this point, the flow changes from oil-continous to water-continous or vice versa. See figures 3,4 and 5.

Measurements have shown that the sensitivity in the two areas depends on the number of windings and whether the coil is wound with standard copper wire or copper tape.

This provides for excellent flexibility where the sensitivity may be optimized for a given application, for example if one wishes to obtain a maximum sensitivity for low water fractions in oil. In another application one may wish a maximum sensitivity for low oil fractions in water. This requires two different coils according to the invention, and if two coils according to figure 1 are combined, a maximum sensitivity over the whole of the meassuring area (see figures 4 and 5) is obtained. A possibility to compensate for changes in salinity is another advantage which may be obtained.

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